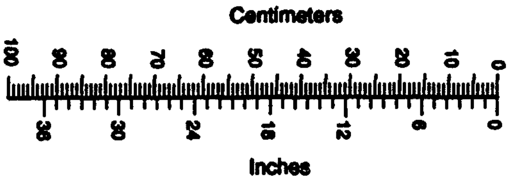
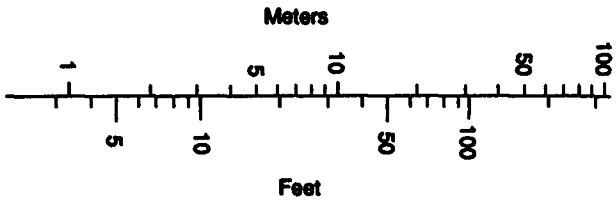
Cold Regions Technical Digest
No. 94-1, March 1994

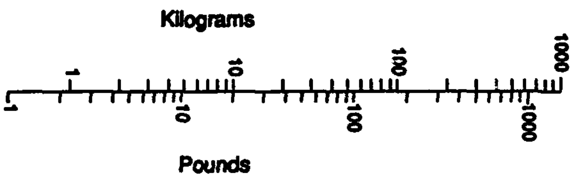
Clearing Ice for Bridging Operations

Deborah Diemand

US Army Corps
of Engineers
Cold Regions Research &
Engineering Laboratory







Accesion For

NTIS CRA&I ☒
DTIC TAB ☐
Unannounced ☐
Justification ....

By ....
Dist. ibution /

Availability Codes

Dist	Avail and / or Special
A-1	

CRREL's *Cold Regions Technical Digests* are aimed at communicating essential technical information in condensed form to researchers, engineers, technicians, public officials and others. They convey up-to-date knowledge concerning technical problems unique to cold regions. Attention is paid to the degree of detail necessary to meet the needs of the intended audience. References to background information are included for the specialist.

AD NUMBER	DATE 6/1/94	DTIC ACCESSION NOTICE
1. REPORT IDENTIFYING INFORMATION A. ORIGINATING AGENCY USA CRREL HANOVER NH 03755 B. REPORT TITLE AND/OR NUMBER CRTD 94-1 CLEARING ICE FOR BRIDGING ... C. MONITOR REPORT NUMBER ~~BY DEBORAH DIEMAND~~ D. PREPARED UNDER CONTRACT NUMBER		**REQUESTER:** *1. Put your mailing address on reverse of form.* *2. Complete items 1 and 2.* *3. Attach form to reports mailed to DTIC.* *4. Use unclassified information only.* *5. Do not order document for 6 to 8 weeks.*
2. DISTRIBUTION STATEMENT UNLIMITED		**DTIC:** *1. Assign AD Number.* *2. Return to requester.*

DTIC Form 50 DEC 91 PREVIOUS EDITIONS ARE OBSOLETE

COLD REGIONS TECHNICAL DIGEST No. 94-1, March 1994

USA Cold Regions Research and Engineering Laboratory
Hanover, New Hampshire 03755-1290

Clearing Ice for Bridging Operations

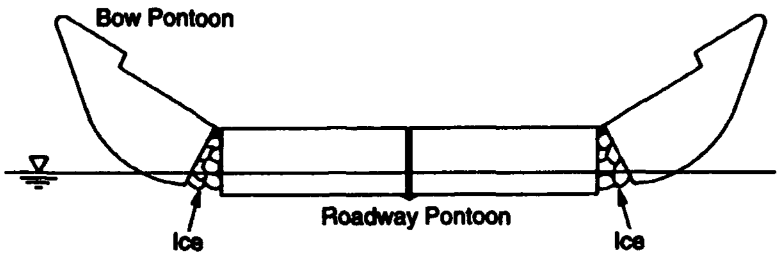
Deborah Diemand

If river ice is not strong (thick) enough to allow it to be crossed by driving vehicles directly on the ice cover, then alternative means of crossing must be implemented. If the river is narrow enough, an Armored Vehicle Launching Bridge (AVLB) or a Medium Girder Bridge (MGB) can be used. However, if the river is too wide for either of these and too deep to ford, it may be necessary to use a float bridge (ribbon bridge) as described in TM 5-210 and TM 5-5420-209-12 (U.S. Army 1970, 1992). The ribbon bridge is designed for deployment and use in water using flotation to aid in unfolding of the individual bays. On a solid ice surface, the bridge is difficult to unfold because the bow pontoons, hinged on the upper surface of the section, cannot open freely. The pontoons will either become jammed with snow, if it has not been cleared from the area, or dig into the ice with the protruding tie-down pins. Both unfolding the bays and connecting them together require a great deal of machinery and time-consuming adjustment. Therefore, it is preferable to remove the ice cover at least in the area where the bridge sections will be launched. Before installing the bridge, the ice cover must be broken up and all fragments removed so that the bridge can be launched in clear water.

Two common methods of fragmenting the ice are cutting it with chain saws and blasting. The resulting ice rubble may be cleared by bulldozing or by submerging the ice slabs under the remaining ice cover. Ice slabs can be moved by poling or with the Bridge Erection Boat (BEB) either by itself or using an unfolded bridge bay as a pusher. In any case, the rubble must be removed because it will be-

The author, a physical scientist, is a member of CRREL's Applied Research Branch.

come trapped between the bow pontoons and the roadway pontoons during deployment (Fig. 1) as well as between bays during attempts to connect them, as shown in Figure 2. The method of clearing the ice rubble will be governed by site conditions and availability of equipment.



1. A ribbon bridge section cannot unfold properly in ice-choked waters because ice chunks are caught in the space between the bow pontoon and the roadway pontoons, preventing the bridge section from lying flat.

2. Connecting ribbon bridge sections to one another is hindered by ice fragments that must be cleared from between the sections before they can be latched.

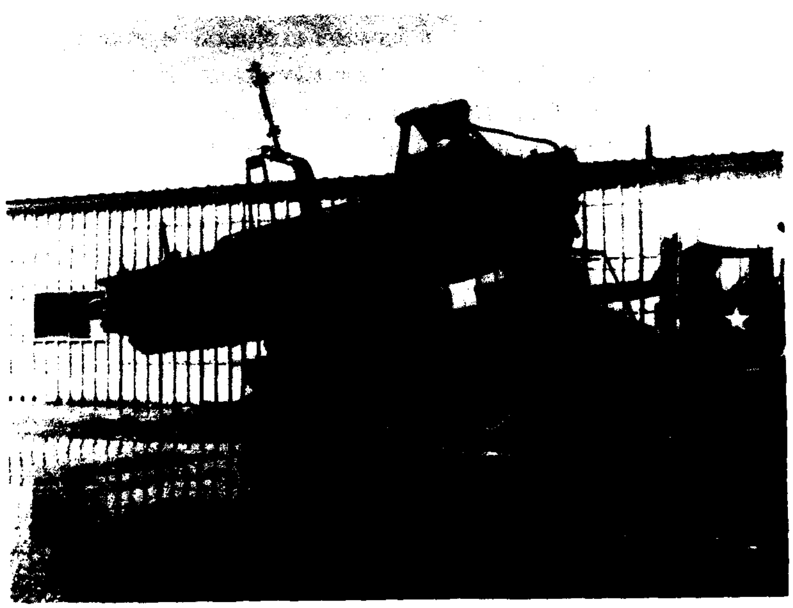
Breaking up the ice

Various methods have proven successful in breaking river ice to form a crossing lane in which to deploy a floating bridge. The choice of the optimum method will depend upon the tactical situation, the thickness of the ice and especially the materials and equipment available. Current speed should also be considered with regard to its influence on boat (and bridge section) launch or maneuvering and on clearing of ice fragments. Some operations will be aided by a swift current (e.g., ice clearing) while others may be seriously hampered (e.g., bridge assembly). For thin ice covers (up to about 6 in.) a BEB can be used as an expedient icebreaker. For thicknesses between about 6 to 20 in., a chain saw works reasonably efficiently. Explosives can be used on ice of any thickness. Guidance for the ice thickness required to drive different vehicle classes directly on the ice cover is given in Appendix A.

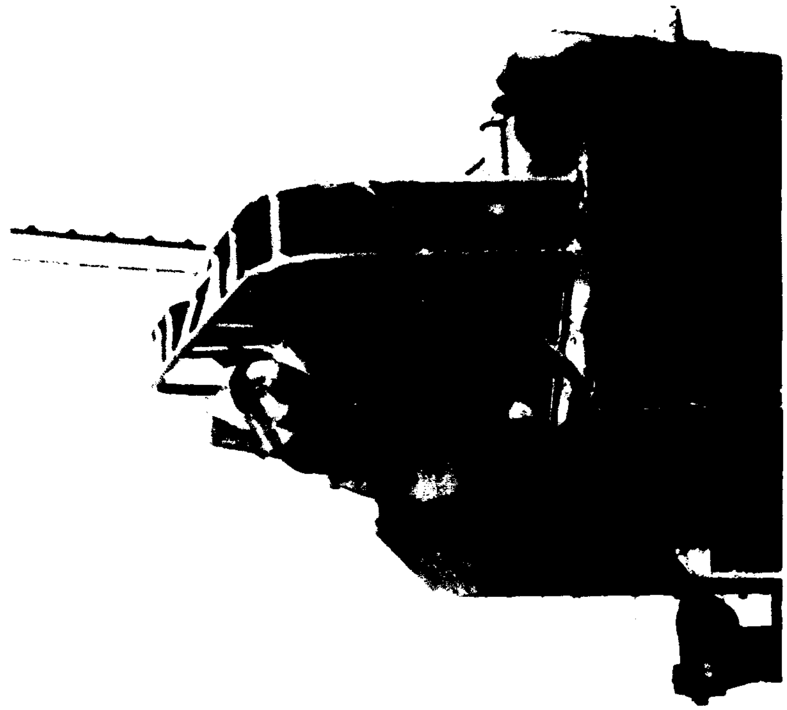
Bridge Erection Boat (BEB) as icebreaker

Experience has shown that an ice cover up to 6 in. thick can be fairly easily removed from a crossing zone using a BEB (Fig. 3). This aluminum-hulled boat weighs about 4 tons and is driven by hydrojet units that provide both propulsion and steering (Stubstad et al. 1984, U.S. Army 1981). An ice sheet 4 in. thick or less can be broken very quickly and efficiently by driving the boat at a constant low speed through the ice. A straight crack is formed ahead of the boat and widened by the bow. Ice is pushed aside by the passage of the boat. At thicknesses of 4–6 in. in unbroken ice, the boat rides up on the ice and breaks it, creating a semicircular crack pattern in front of the boat. The boat must then back away from the area while the ice debris is removed before the next ice-breaking attempt. This is a much slower process than that for the thinner ice. In ice thicker than 6–8 in. the boat may ride up on the ice without breaking through, becoming stranded. With the water intakes clear of the water it can be very difficult to return the boat to the water. At thicknesses between about 4 and 6 in. a combination of the two breaking patterns occurs. At all times the boat should be operated at low speeds. Engine speeds should never exceed 1500 RPM, and if possible should be kept below 1000 RPM.

For the most part, the BEB operates well in ice-clogged areas. The water intakes may occasionally become clogged, but this can be quickly remedied using the standard back-flushing procedure. The BEB's only problem in this environment is backing up. Chunks of ice can become jammed between the lower tubular frame section of the diving platform and the external jet and steering components of



3. Bridge Erection Boat [BEB].



4. Jet and steering assembly of the BEB.

the propulsion system (Fig. 4). When this happens, directional control may be difficult or in some cases totally impossible. Clearing of the ice is also very difficult because the area is not easily accessible.

Procedures for launching the boat in a frozen river are well described by Stubstad et al. (1984).

Explosives

The surface effect of an underwater explosion depends primarily on the depth at which the explosion takes place. If it is very deep there will be no discernible effect, while if it is very close to the surface, there will be a great deal of noise, smoke and spray.

The charge depth at which a certain surface effect will be produced is governed by charge size and, to a lesser extent, by explosive type and ice type. It is therefore useful to scale the charge depth, d, with respect to the charge weight, W, so that dissimilar charge sizes can be compared. This is conveniently accomplished by cube-root scaling such that the scaled depth for a charge size of 1 to 1000 lb and depth and 0 to 30 ft is represented by $d/W^{1/3}$.

The behavior of an explosion in water with an ice cover is very similar to one without an ice cover. The crater produced by an explosion is defined as the area of the ice where the ice is completely (and obviously) broken, such that the fragments are no longer even weakly attached to the ice sheet. Radial and circumferential cracks may exist beyond the crater, but the integrity of the sheet will not be significantly reduced. Analysis of available test data in ice less than 14 ft thick and with a charge weight of less than 660 lb suggests that cube root scaling can be used for all linear dimensions, including ice thickness, charge depth, and resulting crater radius (Mellor 1986). In these conditions it has been found that the *optimum* blast, that is, with the largest scaled crater radius, is obtained with $t/W^{1/3} \approx 0.9$ ft/lb$^{1/3}$ (0.36 m/kg$^{1/3}$), where t represents the ice thickness. The optimum charge weight, W_{opt}, is therefore:

$$W_{opt} \approx 1.4\, t^3 \text{ lb} \qquad \text{with } t \text{ in feet}$$
$$W_{opt} \approx 21\, t^3 \text{ kg} \qquad \text{with } t \text{ in meters} \tag{1}$$

The best result is obtained with the charge almost in contact with the underside of the ice, i.e., with the charge 0 to 0.5 ft/lb$^{1/3}$ (0 to 0.2 m/kg$^{1/3}$) below the ice cover. The probable radius of the resulting crater will then be:

$$R_c \approx 6.56\, W^{1/3} \text{ ft} \qquad \text{with } W \text{ in pounds}$$
$$R_c \approx 2.6\, W^{1/3} \text{ m} \qquad \text{with } W \text{ in kilograms} \tag{2}$$

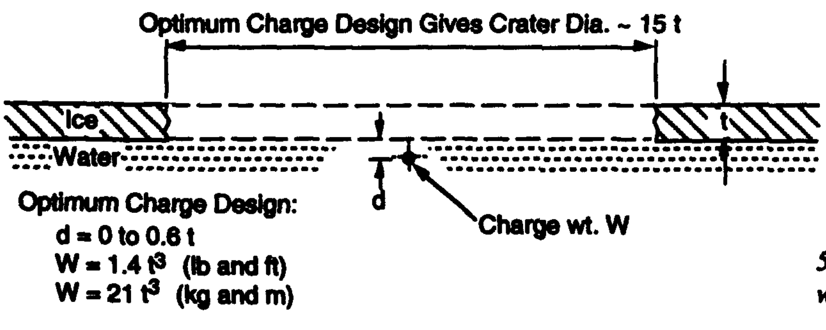
A much simpler rule of thumb for optimum crater size is obtained by expressing dimensions as multiples of the ice thickness t. The charge depth d_c (below the base of the ice) is then

$$d_c \approx 0 - 0.6\, t \tag{3}$$

and the optimum crater diameter D_c is

$$D_c = 2R_c \approx 15\, t \tag{4}$$

These guidelines are given in Figure 5 and Table 1.



5. Explosive charge in the water beneath the ice.

Table 1. Optimum charge weight and placement for ice blasting

Ice thickness		*Optimum charge weight*		*Maximum depth below ice*		*Approximate crater diameter*	
(ft)	*(m)*	*(lb)*	*(kg)*	*(in.)*	*(cm)*	*(ft)*	*(m)*
0.50	0.18	0.25	0.1	4	11	8.0	2.6
0.75	0.22	0.50	0.2	5	13	11.0	3.3
1.00	0.32	1.50	0.7	7	19	15.0	5.0
1.25	0.40	3.00	1.4	9	24	19.0	6.0
1.50	0.48	5.00	2.3	11	29	23.0	7.0
1.75	0.56	8.00	3.6	13	33	26.0	8.0
2.00	0.64	12.00	5.4	14	38	30.0	10.0
2.25	0.70	16.00	7.3	16	42	34.0	11.0
2.50	0.81	25.00	11.3	18	49	38.0	12.0
2.75	0.87	30.00	13.6	20	52	41.0	13.0
3.00	0.95	40.00	18.1	22	57	45.0	14.0
3.25	1.03	50.00	22.7	23	62	49.0	15.0
3.50	1.09	60.00	27.2	25	65	53.0	16.0

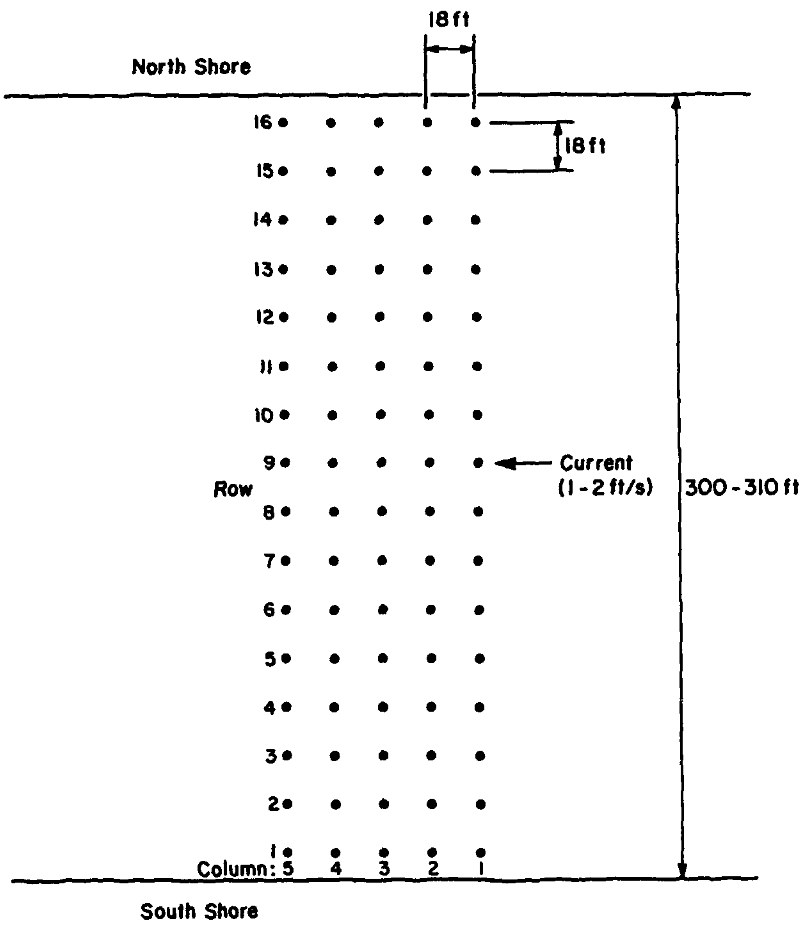
The spacing of individual charges in an array depends not only on charge weight and ice thickness but also on the proximity of other charges. Interference between individual explosions can break up the ice more effectively because of base surge and violent wave action, resulting in an effectively greater crater diameter. This synergistic effect is more pronounced in a two-dimensional array (pattern charge) than it is in a linear array (row charge). Thus the spacing of charges in a linear array will be roughly one-half to one optimum crater diameter for good ice fragmentation, while that in a two-dimensional array will be one to one and a half crater diameters.

If it is not practical to emplace the many small charges specified for optimum blast conditions in relatively thin ice, larger charges can be used whose crater sizes will be roughly the same size as they would be in an optimum blast. As shown in Table 1, a 25-lb charge used in ice 1 ft thick will produce a crater 38 ft in diameter. Bear in mind, though, that the placement depth should be equivalent to that of the heavier charge, that is 3 to 4 ft including ice thickness, rather than the 12 to 19 in. specified for the smaller charge. Further information on blast design is available in Mellor (1986) and Mellor (1982).

While an ice cover can be successfully broken up using explosives, the ice probably will not be thrown clear of the water. Test shots are required to determine charge size and spacing. Table 2 and Figure 6 show the results of test shots and the charge pattern used to break up an ice cover on the Imgiin River (Korea) in 1986

Table 2. Details and results of four test shots on the Imgiin River in South Korea in January (after Coutermarsh 1987).

Test	*Explosive*	*R.E. factor*	*Weight (lb)*	*Weight (kg)*	*Ice thickness (in.)*	*Ice thickness (cm)*	*Blasted hole diameter (ft)*	*Blasted hole diameter (m)*
1	C4	1.35	1.25	0.57	9	23	18	5.5
2	TNT	0.92	1.00	0.45	11–11.5	28–29	8	2.5
3	C4	1.34	2.50	1.1	11	28	20	6
4	C4	1.34	2.50	1.1	11	28	16.5 × 34	5 × 10



6. Charge pattern used to break up the ice cover on the Imgiin River, South Korea.

(Coutermarsh 1987). The ice was about 10 in. thick at the site. Each of the holes in columns 1, 2, 4, and 5 had one stick of C4 explosive (1.25 lb) suspended 3 in. below the ice on a string secured to a stick across the top of the hole. Some of the holes in column 3 had two sticks (2.5 lb) of C4 and the rest four sticks (5 lb) in hopes that the rubble could be blown clear of the channel; this proved unsuccessful. A ring main was laid out to connect all the charges using an electrical primary detonation with a time fuse as a backup. The result of the detonation was a crossing zone of fragmented ice about 95 ft wide across the entire river. The ice fragments ranged in size from about 25 ft^2 to slush particles. The process of laying out the grid, chopping the charge holes, preparing the charges, and detonating took about 5 hours with inexperienced personnel.

Many other explosive methods have been tested informally. The fastest and most promising method in terms of the size of the ice hole created was use of a bangalore torpedo. This is an explosive device supplied in 5-ft-long metal tubular units that are designed to be attached end to end to produce a linear charge of the desired length. Shrapnel is produced on detonation; therefore, these devices should be used with great care. In one trial, a 40-ft-long bangalore torpedo was placed directly on the surface of the ice (Coutermarsh 1987). The study did not specify what type of bangalore was used, but a 40-ft section would have either 72 or 84 lb of explosive, resulting in 1.8 or 2.1 lb/ft of explosive. It took one squad 6 minutes to place the 40-ft-long bangalore on the ice, and the resulting crater, in 16- to 18-in.-thick ice, was 10 by 40 ft. Embedding the torpedo in the ice reduced the crater size greatly.

Another promising method was a daisy chain of M19AT (anti-tank) mines. The mines were primed with six wraps of DET cord and were placed bottom down under the surface of the ice. Installation time was 2 minutes per mine and the resulting crater diameters were 20 to 21 ft at each mine (Coutermarsh 1987).

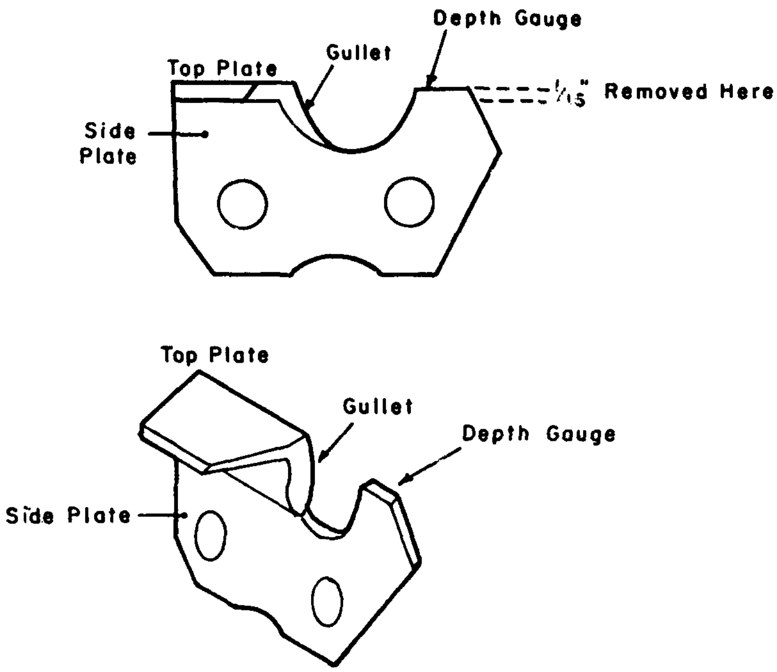
If the ice is broken up by blasting and the river current is not sufficient to move all the ice rubble to the downstream side of the bridge channel, then it will have to be removed mechanically or by hand.

Compressed gas blasting

Compressed gas blasting is broadly similar to the use of explosives. Trials have been conducted using both compressed air and compressed carbon dioxide (Mellor and Kovacs 1972). This can be a useful technique if ice breaking must be done carefully, such as close to a ship's hull or other structure, or if pollution is a concern, but it does require bulky, specialized apparatus and cannot break as much ice in as short a time as explosives. A compressed air shell capable of producing a crater the same size as that of a single stick of dynamite weighs more than 30 lb and is $2^{5/8}$ in. in diameter and 5 to 10 ft long with a discharge pressure in the order of 10,000 psi. In general, this is not a practical approach to routine or military ice-breaking.

Chain saws

Another way to reduce the ice cover to manageable blocks is by using a chain saw. This allows the creation of a cleaner channel and the size of the ice floes can be controlled. However, this technique is

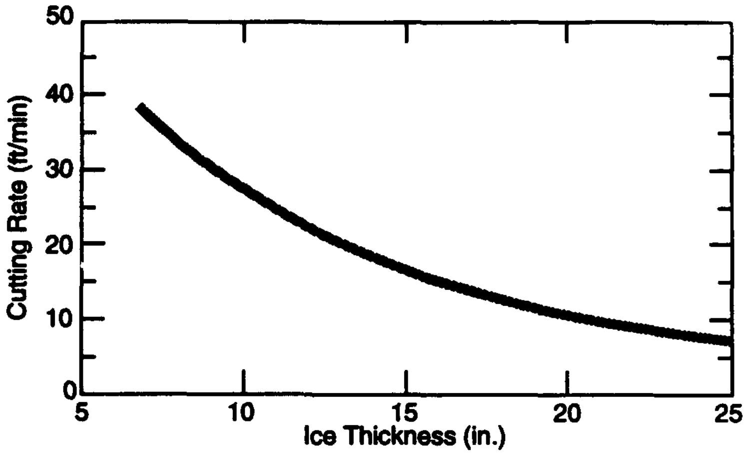


7. Modified tooth on a skip-tooth chain used for ice cutting.

labor intensive and can be difficult. The chains tend to jam, especially when the ice is thick; this problem can be reduced by dipping the bar into a bucket of gear oil occasionally.

When using chain saws to cut ice, the cutting rate is highly dependent upon ice thickness and chain design. A conventional chain has a left or right cutting tooth on every other link, while a skip-tooth chain has two connecting links between adjacent teeth. Skip-tooth chains cut ice faster than conventional chains, but are still substantially slower than chains with the gauge filed down. Chains with the gauge filed down are more efficient and can cut deeper into the ice, producing large chips rather than small shavings. Coutermarsh (1989) compared the performance of a standard skip-tooth chain and a modified version with the gauge filed down about 1/16 in. as shown in Figure 7. He found that the cutting rate of the modified chain was up to 81% higher than the standard skip-tooth chain. There is some evidence that complete removal of the gauge will increase the cutting rate still more.

Another important factor in the cutting rate is the ice thickness. When the ice thickness approaches or exceeds the bar length, the cutting rate is greatly reduced. The effective length of the bar can be increased by making a V-shaped notch along the top of an incomplete cut, but the amount of ice that must be removed and the time needed to do so make this a very inefficient process. Figure 8 shows the relationship between cutting rate and ice thickness that Coutermarsh



8. Cutting rate versus ice thickness using a modified skip-tooth chain on a 24-in. bar.

(1989) found in his work with three different ice thicknesses: 7 in., 11 in., and 25 in. Ice thinner than 7 in. can be broken up with a boat without cutting, while ice thicker than 25 in. cannot be efficiently subdivided with a chain saw. The bar length used in Coutermarsh's study was 24 in.; however, the cutting rate would be very slow even using a longer bar.

Hot-water drills

Thermal drills, steam jets, and water jets may be useful in cutting ice in the crossing zone, but are not recommended for all applications because of their power requirements and the relative newness of the technology and limited availability of the necessary equipment.

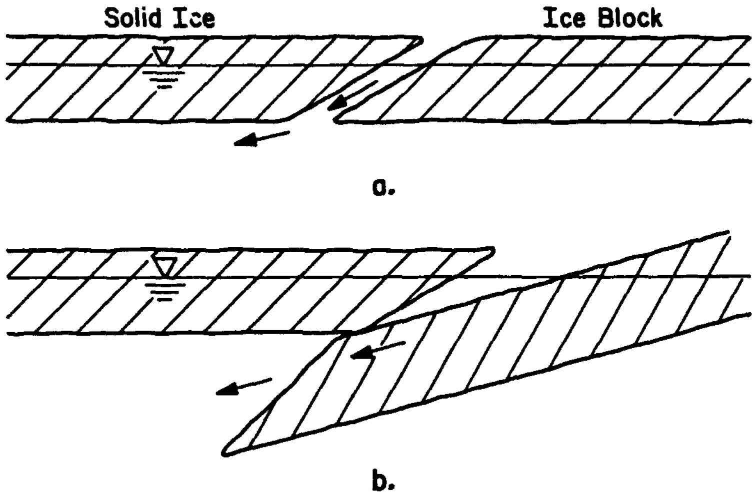
Ice removal

Relatively thin river ice (say, 8 in. or less) is easy to break or cut, but not easy to clear from a channel to leave open water. There are three broad possibilities: 1) dispose of ice fragments beneath the adjacent intact ice sheet, relying on river current to move the debris downstream; 2) lift ice fragments onto the intact ice sheet adjacent to the channel; 3) transport ice fragments to the shore for disposal.

Initially, the floes can be moved with poles and boat hooks, and then BEBs can be used to move them farther. Relatively thin floes can be pushed under the downstream ice sheet or pushed toward shore and removed with a bulldozer. A crane or transporter boom can be used (Coutermarsh 1990) if the beach drops off sharply or the ice is thick, or both.

Submerging ice slabs

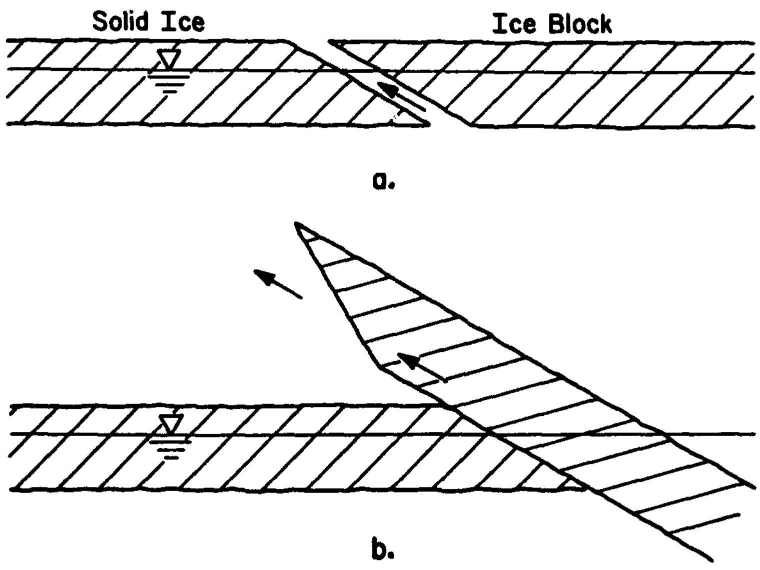
Submerging ice slabs is a fast, effective technique for a limited number of fairly small thin floes. It is best done by men standing at the edge of the downstream side of the bridge channel who can push the floes down and under the uncut sheet using boat hooks, poles, bars or similar implements. The maximum size of floes that can be



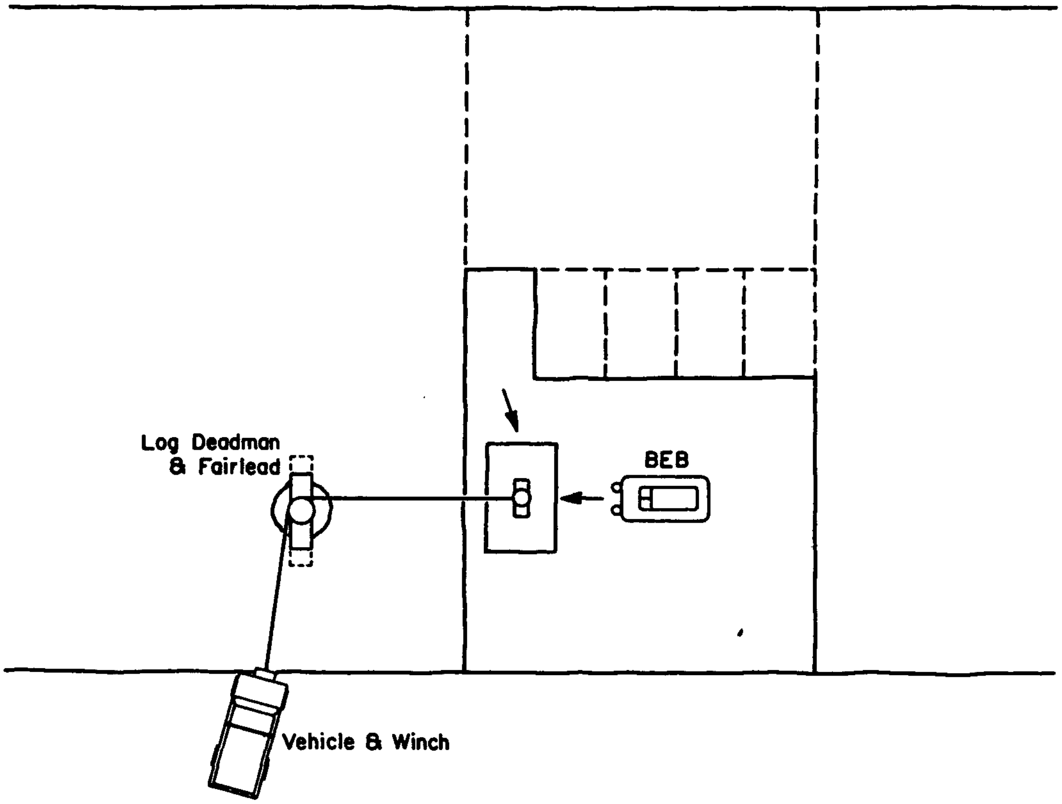
9. Ice sheet cut so that loose section can be pushed beneath the intact sheet.

effectively handled in this way appears to be about 6 by 10 ft, and having been pushed beneath the ice sheet they will probably not move downstream very far since they float up under the unbroken sheet and ice-on-ice friction prevents their traveling farther. As many as three successive floes can be disposed of in this way, but with increasing difficulty. Another problem is that the floes break while being jabbed and pushed with poles and crowbars (which themselves have a tendency to disappear into the river).

It may prove easier to slide the ice floe under the sheet if it has been cut on an angle as shown in Figure 9, and it may be possible to grapple onto the upper surface of the sheet if the angle is cut in the other direction as shown in Figure 10. A winch can be used directly if the ice is thick enough to support the weight of a vehicle equipped



10. Ice sheet cut so that loose section can be pushed on top of the intact sheet.

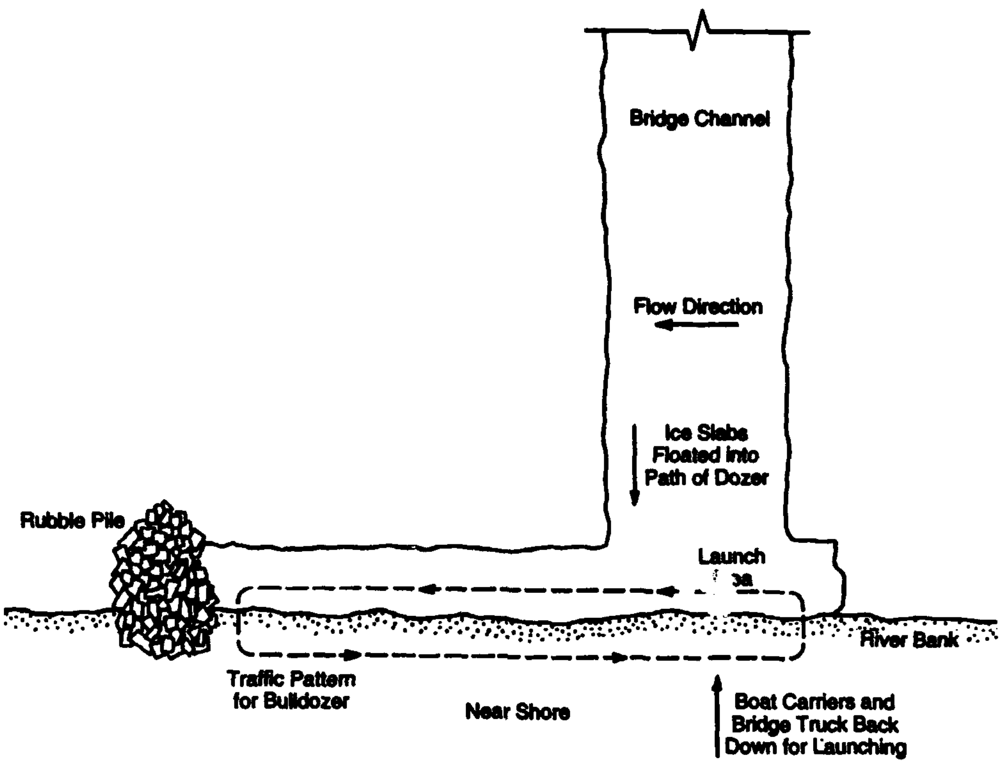


11. Expedient arrangement to pull ice slabs onto the surface of the intact sheet for removal.

with one. If not, then a series of deadman fairleads must be embedded in the ice to direct the cable toward the shore as shown in Figure 11.

Bulldozers

Removal of the ice with bulldozers works very well if the river bank slopes gently into the river. ACEs (Armored Combat Earthmovers) and CEVs (Construction Engineer Vehicles) may also be used. The following procedure has been used successfully (Mellor and Calkins 1988) and may be modified as the situation requires. The bulldozer should first walk over the grounded ice to fracture it and to break the bond with the gravel. At the same time, the outer track will put cracks in the floating ice. The machine then moves out into shallow water and begins pushing ice in the downstream direction. In this way a clearing basin is created parallel with the shore and perpendicular to the bridge channel as shown in Figure 12. The idea is to float ice from the bridge channel into the clearing basin, and then move it away by bulldozing. The blade should be kept high enough to clear the river bottom, since any digging in the river bed quickly develops pits and ridges that create very bad working conditions. If



12. Method of removing ice using a bulldozer. Ice slabs can be moved into the path of the bulldozer either by poling or using BEBs.

the river bed is disturbed in this way, it should be smoothed out again by backblading. If there is a long stretch of gently sloping shoreline, the clearing basin can be 230–260 ft (70–80 m) long.

Ice debris should be accumulated downstream of the bridge channel; in this case it was pushed to the downstream end of the clearing basin. To prevent unwanted ice from floating back into the basin, it should be grounded. The easiest way to do this is to finish the downstream push by angling towards the beach so that the debris in front of the blade is resting on the river bed and does not float back as the bulldozer backs off. As the pile of debris grows, it is firmly grounded, even in relatively deep water, and ice can be added to the pile by jamming it firmly against the ridge. The object is to have the ice debris stay in the pile when the bulldozer backs off (Fig. 13).

In operating the bulldozers, one-way traffic is maintained. If the machine travels backwards through the water when returning to the starting point, it draws ice debris after it, thus hampering the clearance operation. It is best to have the machine turn back onto the dry beach when it backs off from the debris pile. It then travels upstream on the beach, and reenters the water at the upstream end of the clear-

13. Well-grounded rubble pile. The bulldozer will now return to the launch area on the shore and push another load of rubble downstream.

ing basin as shown in Figure 12. Two bulldozers working side by side are more efficient than a single machine because transverse spillage from the blade is reduced. Ice slabs from the main bridge channel are pushed into the path of the bulldozer, first by poles and later by bridge boats. The bulldozer should be kept supplied in this way so that it can operate without a break. Fresh ice slabs should be moved from the bridge channel into the clearing basin as soon as the bulldozer passes in the downstream direction.

When the bridge channel is completely clear across to the opposite river bank, the bulldozer makes a final cleanup along the shoreline. Small ice fragments are then floated to the downstream end of the clearing basin by propwash from the BEBs.

Bridge erection boats for ice removal

One or more BEBs can be launched as soon as there is a sufficient area of open water at the river bank. The old 27-ft BEB has limited capability for icebreaking; the new boat has somewhat more icebreaking capability (Stubstad et al. 1984). To break ice, the bow of the boat should ride up onto the ice. This can be achieved by trimming the boat down in the stern. In the old 27-ft boat, it is sufficient to move a crewman to the aft end of the cockpit, and either to move heavy items aft or to remove them from the boat. With the boat trimmed for icebreaking, it can be driven up onto the ice, but the maximum safe speed has not been established, so the speed should be kept as slow as possible.

A bridge section can be used to clear a wide swath by pushing it through the rubble with two or more BEBs as shown in Figure 14. The BEB may also be used alone to push the ice fragments out of the

14.Section of the ribbon bridge, pushed by several BEBs, being used to clear a wide path through the ice rubble.

channel. However, the standard push-knees on the boat do not extend down to the water level, either when trimmed for icebreaking or for normal operation, and therefore will not engage with ice floes unless the boat is trimmed down in the bow by making sure that heavy items of loose equipment are stowed well forward, or by having a crewman sit up on the bow (see Fig. 15). The same procedure allows the boat to stabilize itself against the unbroken ice sheet when using the propwash to clear ice fragments. The boat should approach the ice *very slowly* to avoid damage or loss of the push-knees. This is true

15. BEB pushing an ice slab. The push knees are inverted to reach the ice and the boat is weighted down in the bow.

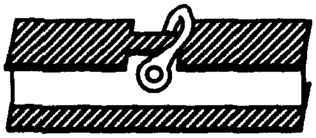
16. Three BEBs braced against the unbroken ice sheet and clearing small ice fragments away from the launching area using their propwash.

whether the intent is to push the floe or to stabilize the boat to use the propwash.

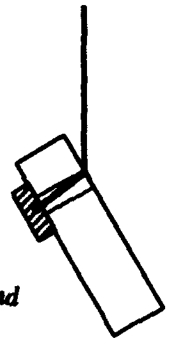
The boat can clear small fragments over a limited area by using the propwash to create a current. The bow should be braced *carefully* against a convenient edge of the unbroken ice, with one or more men in the bow to keep the push-knees in contact. Throttles are opened *slowly*, and then kept at a constant setting. Violent bursts of throttle serve no useful purpose, and only tend to break the ice that is holding the boat. The propwash diffuses, and provides only a gentle current for two or more boat lengths astern. It is not efficient for transporting ice floes or large accumulations of debris. The most valuable application for propwash removal of ice rubble is to clear small pieces of debris from the launching area just before a bridge bay enters the water. This process is shown in Figure 16.

Transporter booms

Transporter booms work well in lifting 5-ft by 8-ft by 24-in. blocks of ice weighing roughly 5000 lb. A rectangular hole, cut off-center in the block, with a length of I-beam and shackle inserted in the hole, will allow the transporter boom to lift the block out of the water. This arrangement is shown in Figure 17. Once the ice block is lifted to the level of the boom (Fig. 18), the boom is lowered onto the truck bed with the ice block and can be carried away for disposal. Once the block has been prepared, this is a very quick and neat method of ice removal. It allows the approach to the crossing area to be kept clear of ice and will also work in areas where there is only a narrow approach to the crossing zone, since it does not require lateral movement of equipment such as in bulldozer operations. The trucks can approach and depart on the road that will be used for the bridge



a. I-beam fitted with shackle for easy attachment.



b. I-beam inserted through a hole in ice slab and toggled in place for lifting.

17. Short section of I-beam used to lift a thick ice slab from the water using a transporter boom.

18. Ice slab being lifted onto the bed of a transporter truck.

itself. This is, however, a relatively inefficient process if the ice is fairly thin as it will break under its own weight when it is removed from the water. Thus much smaller fragments will be taken with each load.

Power shovels, loaders, and backhoes

Power shovels, loaders and backhoes can be used to clear the ice from the launch area, but the process is quite slow because of the relatively small amount of ice that can be picked up with each load. Also, loaders will need room to maneuver. Trucks must be available and also free to maneuver near the launch area, and a disposal area must be available nearby to dump the accumulated rubble. As soon as the launch area is clear enough to put a boat in the water, the boat

a. Unbroken ice cover before ice breaking and removal operations.

b. The same area after the bridge has been nearly completed. Note the ice rubble piled along the shore.

19. Photographs taken from roughly the same position on the Imgiin River in South Korea.

can help by pushing ice fragments into the shore for removal, but other ice removal methods are preferable. In one operation described by Coutermarsh (1987), it took 28 hours to clear a 328- × 65.5-ft crossing zone using a bridge boat, a power shovel, and a front-end loader.

After all cleanup operations are completed a wide path across the river will have been created with open water at the upstream end, including the area where the ribbon bridge is to be installed, and some residual broken ice at the downstream edge. Figure 19 shows a frozen river before clearing operations have begun and the same river with the bridge nearly installed.

Maintenance and removal of the bridge

In order to retrieve the bridge sections after use, the sections must be clear of ice for the same reasons as during launch; ice fragments caught in the hinged areas will prevent proper folding of the section. During the period of deployment the bridge should be kept clear both of floating fragments and newly formed ice. The latter may form as a collar around the bridge sections, which should be removed by driving heavy vehicles across the bridge every hour or two to break off the ice.

In any case, the bridge should be removed before ice breakup either due to water release upstream or through natural processes. Once the ice cover begins to move orderly bridge removal will not be possible.

Conclusions

The choice of a suitable method of breaking up the ice cover depends on the tactical situation, environmental conditions (ice thickness, current strength, shore conditions, etc.) and equipment at hand. The use of explosives will probably be faster than using chain saws, but the ice clearing operation will be longer.

Literature cited

Coutermarsh, B.A. (1987) Tactical bridging during winter—1986 Korean bridging exercise. USA Cold Regions Research and Engineering Laboratory, Special Report 87-13.

Coutermarsh, B.A. (1989) Factors affecting rates of ice cutting with a chain saw. USA Cold Regions Research and Engineering Laboratory, Special Report 89-24.

Coutermarsh, B.A. (1990) Winter bridging exercise on thick ice—Fort McCoy, Wisconsin 1988. USA Cold Regions Research and Engineering Laboratory, Special Report 90-10.

Mellor, M. (1986) Blasting and blast effects in cold regions. Part II: Underwater explosions. USA Cold Regions Research and Engineering Laboratory, Special Report 86-16.

Mellor, M. (1982) Breaking ice with explosives. USA Cold Regions Research and Engineering Laboratory, CRREL Report 82-40.

Mellor, M. and D.J. Calkins (1988) Deployment of floating bridges in ice-covered rivers. USA Cold Regions Research and Engineering Laboratory, Special Report 88-20.

Mellor, M., and A. Kovacs (1972) Breakage of floating ice by compressed gas blasting. USA Cold Regions Research and Engineering Laboratory, Special Report 184.

Richmond, P.W. (Ed.) (1991) Notes for cold weather military operations. USA Cold Regions Research and Engineering Laboratory, Special Report 91-30.

Stubstad, J., J. Rand and L. Jackson (1984) Operation of the U.S. Combat Support Boat (USCSBMK I) on an ice-covered waterway. USA Cold Regions Research and Engineering Laboratory, Special Report 84-5.

US Army (1981) Boat, bridge erection, twin jet, aluminum hull. Technical Manual 5-1940-277-10. 16 December 1981, revised 24 June 1988.

US Army (1970) Military floating bridge equipment, Technical Manual 5-210. Headquarters Department of the Army, August 1970.

US Army (1992) Operator's and unit maintenance manual. improved float bridge (ribbon bridge). Technical Manual 5-5420-209-12. Headquarters, Department of the Army, 15 January 1992.

Related publications

US Army Field Manual (1986) Explosives and demolition. FM 5-25. Headquarters, Department of the Army, 10 March, 1986.

US Army Field Circular (1987) Counterobstacle and river crossing operations. FC 90-13. US Army Command and General Staff College, Ft.. Leavenworth, Kansas, March 1987.

US Army, Marine Corps Field Manual (1992) River crossing operations. FM 90-13/FMFM 7-26. Headquarters, Department of the Army, 30 September, 1992.

US Army Field Manual (1988) Engineer combat operations. FM 5-100. Headquarters, Department of the Army, November, 1988.

Appendix A. Ice thickness guidance

FIELD GUIDE
FRESH WATER ICE CROSSINGS
(USACRREL DEC 86)

Vehicle class (wheeled or tracked)	Required ice thickness (inches = $4\sqrt{\text{veh. class}}$) (in.)	(cm)	Distance between vehicles (about 100 × thickness) (ft)	(m)
200 lbs	2	5	17	5
1	4	11	34	11
2	6	15	48	15
3	7	18	58	18
4	8	21	67	21
5	9	23	75	23
10	13	33	106	33
15	16	40	130	40
20	18	46	149	46
25	20	5	167	51
30	22	56	183	56
35	24	6	198	61
40	26	65	211	65
50	29	72	236	72
60	31	79	260	79
70	34	85	280	85
80	36	91	300	91

Before using Table, see REMARKS below

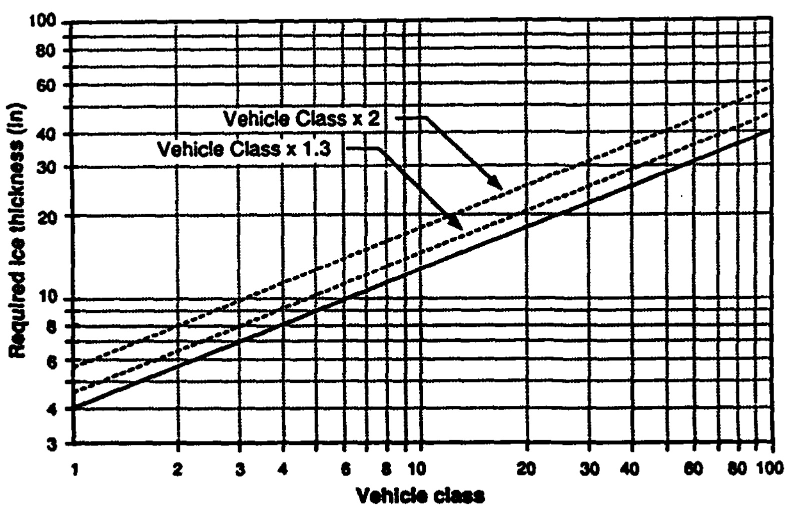
1. If the air temperature has been above freezing for more than 6 of the past 24 hours, multiply the Vehicle Class by 1.3 to obtain the required ice thickness. If air temperature stays above freezing for 24 hours or more, the ice starts to lose its strength, and the Table no longer represents safe conditions. A rapid and unusually large temperture drop causes the ice to become brittle, and for a period of 24 hours, travel may not be safe.

2. For the distance required between two vehicles of different classes, use the distance required for the higher class.

3. If you plan to PARK for extended periods, multiply the Vehicle Class by 2 to obtain the required ice thickness and maintain at least the original distance requirements. Drill a hole through the ice near the vehicle and MOVE if the ice begins to flood.

4. The ice must have WATER SUPPORT. Be very careful CLOSE TO SHORE. Very often the water level will drop after freeze-up. When this happens, the ice close to the shore may no longer have water support.

5. CRACKS are either dry or wet. If dry, they do not penetrate ice cover and can be ignored. If wet, multiply the Vehicle Class by 2 to obtain the required ice thickness and try to drive straight across the cracks (avoid going parallel to wet cracks).



A1. Required ice thickness for vehicle classes.

★U.S. GOVERNMENT PRINTING OFFICE:1994-500-080/00500